RESEARCH NOTES

September 2007

Dynamic Vehicle Navigation in a Peer-to-Peer (P2P) System

(ATMS TESTBED PHASE III FINAL REPORT)

Why Was This Research Undertaken?

Although inter-vehicle communication and information dissemination in traffic networks have been modeled both from various academic perspectives (transportation engineering, electronic engineering and computer science) and at different levels (highly abstract, software protocols and hardware products), no efforts have been found that systematically model and test such a distributed traffic information system based upon peer-to-peer information exchange relative to drivers' dynamic on-line routing behaviors within it. This work focuses on detailed modeling of a self-organizing, distributed traffic information system built upon vehicle-to-vehicle information exchange, with case testing of the pre-trip route-choice and in-trip re-route behaviors of drivers with access to traffic information from the proposed information system.

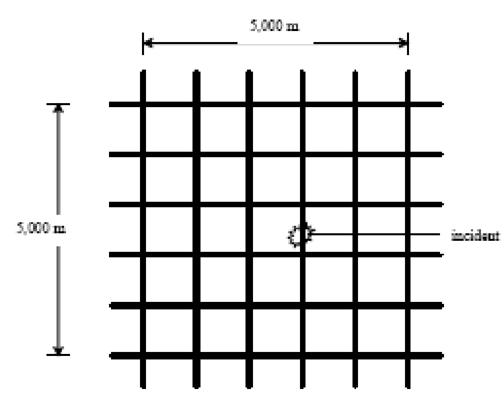
For more in depth discussion and technical analysis, refer to TTR3-10 (Testbed Technical Report).

What was done?

This project focused on detailed modeling of a self-organizing, distributed traffic information system built upon vehicle-to-vehicle information exchange, with case testing of the pre-trip route-choice and in-trip reroute behaviors of drivers with access to traffic information from the proposed information system. Two different large-scale traffic networks, one comprising grid arterial streets and the other a freeway corridor, are tested with respect to different assumptions regarding drivers' route choice behavior including both pre-trip route choice and in-trip re-route behaviors, and different levels of knowledge of daily recurrent traffic patterns. Potential benefits arising from this proposed information system both for travelers with inter-vehicle communication (IVC) and for the whole traffic systems, including all travelers with and without equipment, are demonstrated based on simulation study results.

We used the PARAMICS simulation software to build our simulation modeling framework. Within the micro-simulation modeling framework, some vehicles in the traffic network, equipped with IVC systems, geographic information systems (GIS), global positioning systems (GPS), on-board navigation systems, and in-vehicle computing processors, are assumed to generate floating car data information based on their own experiences, exchange traffic information through peer-to-peer communications, and process incoming traffic information in real-time using their on-board processors. In addition, each vehicle within this distributed traffic information system is assumed to optimize its personal route based on its estimation of current traffic conditions obtained from real-time traffic information propagated in the information network and its understanding of recurrent traffic pattern from its historical traffic information database; based on the assumption that each driver is a rational entity, re-routing decisions are examined. Path-based vehicle navigation is implemented for each driver, in which IVC vehicles follow changeable paths; no-IVC vehicles follow no-changeable paths.

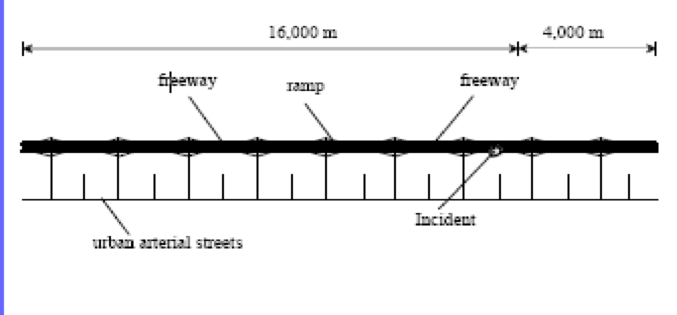
The first test case concerned non-recurrent congestion scenarios in a grid network. The 5,000m x 5,000m network evaluated consists of equally spaced two-lane local street roadways with speed limit of 45 mph; the distance between any two neighboring signalized intersections is 1 km. An incident is assumed to have occurred on a link close to the center of the study grid network.



Network Schematic

This incident is assumed to cause passing vehicles to reduce speed to 5 mph in the direction of the roadway in which the incident occurs and to 10 mph in the opposite direction of the roadway (due to speculator slowing). Three levels of O/D demand were used in our simulation studies to generate light, moderate and heavy traffic flow conditions in the network.

The second test case considered non-recurrent congestion scenarios along a freeway corridor with a neighboring alternative arterial street. The freeway and parallel arterial street are connected by other arterial streets running perpendicular to the freeway and freeway on/off ramps spaced at 2000-meter intervals.



Freeway Schematic

In the simulation, an incident 4000 meters from the far end of the network occurs 30 minutes into the simulation and lasts for 30 minutes; owing to the blockage caused by the incident, vehicle speed in that direction is reduced to 5 mph near incident location. Three levels of O/D demand are used to generate light, moderate and heavy traffic flow conditions, both for the freeway and the arterials.

What can be concluded from the Research?

Several interesting results are obtained from our simulation studies under non-recurrent congestion scenarios in the grid arterial streets network. First, only when IVC market penetration rate is higher than some threshold values, can IVC-capable vehicles make sufficiently accurate estimations of real-time traffic conditions to take re-routing actions. This threshold value is relatively high compared to freeway networks due to the dimensional characteristics of grid arterial networks compared to freeways. Although the relative travel time saving benefits for IVC-capable vehicles from re-routing decrease after reaching maximum values, IVC-capable vehicles always maintain an advantage compared to their counterparts and total system performance improves by their re-routing.

For most cases in the freeway corridor network, as increasing numbers of drivers have accessibility to real-time traffic information from inter-vehicle information exchange, the redistribution of IVC-capable vehicles enables the system to move toward user equilibrium. The characteristics of this freeway corridor network are such that a traveler has significantly fewer choices than in the grid arterial streets. Under normal traffic conditions the freeway system typically has much more capacity and a better level of service than its surface street alternative, leading to many more vehicles choosing to use the freeway system under these conditions; thus, even a relatively small amount of IVC-capable vehicles' re-routing from the freeway to arterial streets may dramatically worsen the traffic conditions on the arterial streets, resulting in a general worsening of system performance under heavy demand.

What do the Researchers Recommend?

This study showed that significant travel time-savings may be possible under a traffic information/management system based on P2P communication. Significant additional study should be undertaken to identify traffic management efficacy, limitations and hardware requirements.

Implementation Strategies

Except under heavy demand levels for the freeway corridor network, overall system performance is shown to improve with IVC-capable vehicles dynamic on-line re-routing as IVC market penetration rate and communication range increase. Although the results indicate that a self-organizing, distributed traffic information system built upon autonomously polling of vehicles as a means for traffic surveillance has the potential to bring benefits to travelers within the IVC information system, more large scale network modeling and analysis is recommended to assess the benefits to the system as a whole prior to any comprehensive implementation strategies can be formulated.

List of Contacts

Principle Investigator:
Dr. Will Recker
Institute of Transportation Studies
University of California, Irvine, CA 92697-3600
Tel.: (949) 824-5642; Fax: (949) 824-8385
Email Address: wwrecker@uci.edu

Other Investigators:
Dr. James Marca)
Institute of Transportation Studies
University of California, Irvine, CA 92697-3600
Tel.: (949) 824-6544; Fax: (949) 824-8385
Email Address: jmarca@translab.its.uci.edu

Contract Manager:
Fred Yazdan
Caltrans, Division of Research and Innovations
Office of Technology Applications
Advanced Testbed Program Branch
6681 Marine Way, Irvine, CA. 92618
Tel.: (949) 936-3462; Fax: (949) 936-3461
Email Address: fred.yazdan@dot.ca.gov